NET+
STUDIO

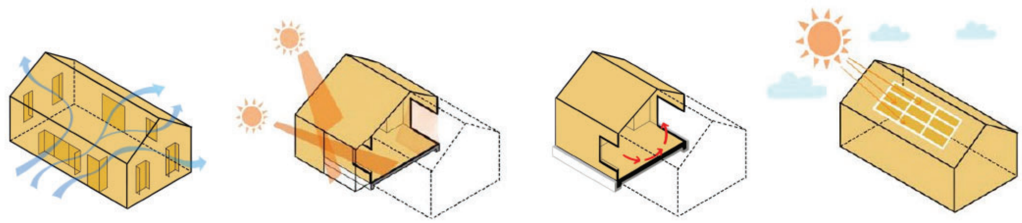
ENGINEERING

Kansas State University

ENGINEERING

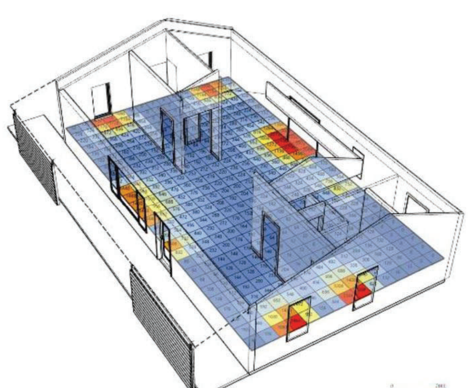
Energy Performance

The Net Positive home's high-performing envelope and the use of passive design strategies reduces heating and cooling loads significantly throughout the year, and during the swing seasons (spring and fall) it will frequently be comfortable without the need for heating or cooling (56%). For that matter, passive strategies like winter sun and natural ventilation to do more work to keep occupants comfortable during the year, leaving the loads for the HVAC system to be much lower. This allows the high-efficiency HVAC system to be smaller and more affordable and also reduces the chances of discomfort. With daylight and high efficiency LED lighting fixtures, heat gains in the house are kept low, which makes it easier to keep it cool in warm months. Most of the energy used by a home will be electric appliances and tank-less water heating. In summary, this home will use a fraction of the energy of a typical home (78% less). Through overall efficiency and passive design, it becomes easy to offset the home's annual energy use with a relatively modest photovoltaic array that fits neatly on the roof and can be mortgaged with the house.

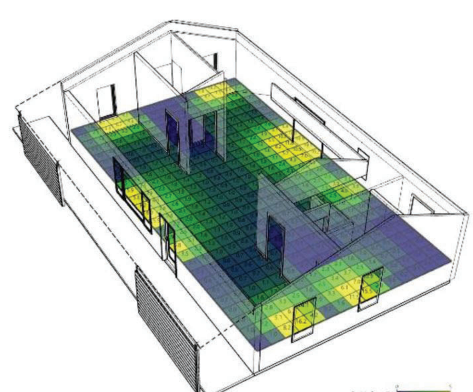


Passive Cooling: Cross Ventilation — Passive Solar: Daylighting and Shading — Passive Solar Heating: Thermal Mass Floor — Solar Energy

The design team used these annual metrics to understand the daylighting potential and glare risk of overall building form, glazing ratios, and shading strategies. Our first step in analyzing our homes daylight potential is to determine its Daylight Factor (DF), a measurement that uses a percentage to predict the "amount of daylight available inside of a room (on a horizontal surface) versus the amount of unobstructed daylight available outside" during cloudy days. For this to be meaningful, we must consider the building properties that can influence the daylight factor percentage. The properties to consider include but are not limited to the size and arrangement of the space, and quantity of glazing areas. We must be careful with how many window openings we provide, because too much light can result in summer overheating or excessive heat loss in winter, as the thermal performance of the glazing layer is typically lower than the rest of a wall.



Illuminance Analysis, 9/21 at 3p



Daylight Factor Analysis

But we must also be careful to avoid a lack of glazing, because the absence of natural light inside a building can raise its electric lighting demand and lead to health concerns for occupants. The higher the DF, the more daylight is available in the room. If a room achieves a DF of 2% of more it is daylit, but electric lighting may still be needed to perform more precise visual tasks. The daylight analysis for our design has estimated our Daylight Factor to be at 2%, which suggests that our home will hit the sweet spot between excessive daylighting and the lack thereof. This means that our design includes no more and no less window openings than it needs; a total of 7 areas of glazing.

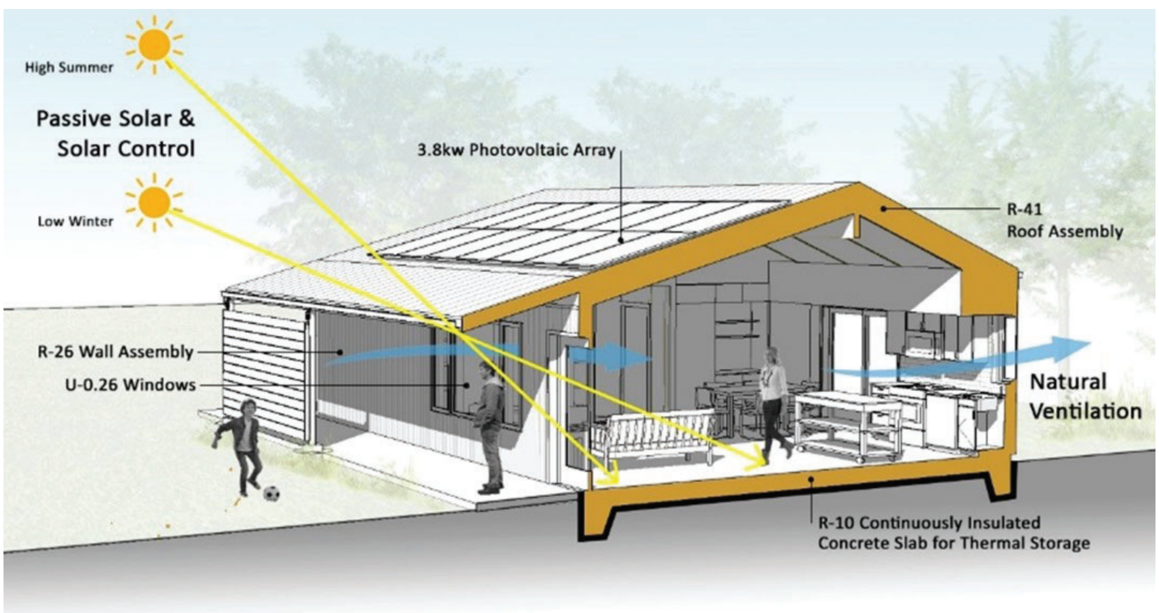
Air handling units, or AHUs, heat, cool, and filter conditioned air and distribute air throughout the house through ducts. The AHU also has a return duct which delivers used air back to AHU where it is filtered and conditioned. For our Net Positive house, we selected a Mitsubishi - M-Series Air Handler for its cost and efficiency. Secondary benefits of this AHU system are its small size, its washable and reusable filter, and its ability to operate in a dehumidification-only mode ('eco mode') which will increase the ability of the home to use natural ventilation and keep occupants comfortable at more economical temperatures.

The small footprint of the house and its high performance envelope also provided a good match for a high-efficiency air-source heat pump, also sourced from Mitsubishi. An air-source heat pump uses the refrigeration cycle in reverse to extract heat from outside air, using the same process as high-efficiency geothermal heating systems but at a fraction of the cost because no heat exchange loops need to be constructed in the ground. Heat pumps don't generate intensely hot heating air like fuel-based furnaces, but they are over 300% more efficient in terms of heating output. For this reason, the modest output of the heat pump and its high efficiency are a great fit for the prototype home, because the heating loads are a fraction of what would be encountered in a typical house. New computer-based controls built into the heat pump system will maintain its high efficiency throughout the range of cold temperatures seen in the Kansas climate.

The envelope of the prototype home was also designed to minimize air leakage, which greatly reduces energy loss versus a conventional home. Beneficial airtightness, however, makes it important to bring in fresh air to maintain a healthy environment. In high-performance homes, mechanical ventilation typically comes in the form of an ERV or Energy Recovery Ventilator, which recovers some of the lost energy from air that is leaving the house by transferring this energy to the incoming fresh air. The ERV system in the Net Positive house is placed independently of the main heating and cooling system and is equipped with two fans: one which draws fresh air into the house while the other pushes stale air out. We implemented the ERV not only for better indoor air quality, but also to help moderate the temperature and humidity of incoming filtered air, creating a more comfortable space. We choose the Panasonic Intelli-Balance™ 100, which will not only stand up to our requirements, but is affordable and has lower maintenance requirements. The ERV will also run as a full-time exhaust in the main, shared bathroom in the house, ensuring that humid air from the bathroom leaves the house and doesn't contribute to mold or condensation. Tank-less water heaters are generally more energy efficient than traditional water heaters with storage tanks. Because tank-less water systems provide water on demand, they eliminate the need for a large storage tank, which is susceptible to standby energy losses (i.e. dissipation of heat from the water over time as it sits unused in your tank). A tank-less water heating system will generally help the user to save money over the system's lifetime, and keeping energy costs low. A considerable advantage of tank-less units is their longer lifespan and ability to be serviced. A standard, high-quality water heater will last roughly a decade, whereas tank-less models' function for twice as long. Tank-less water heaters are also much smaller than bulky tank heaters, requiring less mechanical space: an important benefit for the prototype home. We will be using two tank-less water heaters, an EcoSmart ECO 11 for the independent bath and an EcoSmart ECO 18 for the master bath, kitchen and washer. Because the tank-less water heaters do not rely on a reserve of hot water to meet demand, the entire house has an equal supply of hot water 24/7.

Engineering

The house is specifically orientated on the site to promote the effectiveness of the photovoltaic arrays. The orientation promotes ample daylighting to reduce cooling and heating loads throughout the year. The house has a tightly constructed envelope, with optimized, continuous insulation in the walls, floors and roof that bring down extreme heating and cooling loads. Simple passive strategies like natural ventilation, passive solar, summertime shading of windows, and daylight further reduce energy use. Together these strategies bring energy demand in the home down dramatically, and what energy is needed is offset by electricity generated by a modest photovoltaic system, saving households hundreds of dollars in utility costs per month versus an older home.



The main design concept that relates to exterior and landscape design is the expansion of usable and enjoyable public space from the interior into the exterior. This includes a long, linear front porch that would act as the outdoor preface to the entryway of the home, with large sliding barn doors for situational shading and privacy. This space would be able to be furnished with small tables and chairs that overlook East 8th Avenue, as well as potted plants to accent the front face of the house. A 5-foot overhang covering the porch will help to shade the southern façade during the summer, preventing the sun coming through the southern glazing from overheating the home.

The sliding panels that flank the porch, each weighing roughly 247 lbs, needed to be supported by the porch structure. Working out how the sliding panel rail system would attach led us to resize the beam that was already supporting the porch's roof overhang, and resolve conflicts between the gutter, the supporting rail of the doors, and the structure behind it. Further, the porch structure is composed of a ladder frame which is connected back to the house, rather than constructed of cantilevered rafters. Using a ladder frame simplified prefabrication of the house while also ensuring that insulation could continue unbroken at the transition between wall and roof, preventing potential thermal bridging and air leakage. The south side of the porch is supported by a built-up beam that rests on steel pipe columns that will be prepared off-site with base plates and brackets to speed construction.

Operations

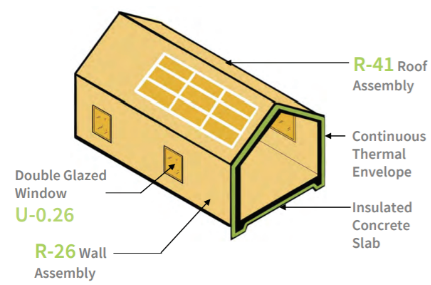
To ensure the performance of all operations and keep the building operating efficiently, we choose energy star rated appliances and energy saving features. To maximize the benefits of the on-site electricity being generated the home will use all electric appliances to reduce energy costs.

Household appliances are including as below:

-Energy Star Rated Refrigerator with freezer
-Self-convection oven with cooktop
-Energy Star Rated washer
-Energy Star Rated dryer
-2 Ecosmart Tankless Electric Water Heaters:
-ECO 18 for the kitchen, master bedroom, and laundry
-ECO 11 for the shared bathroom

Materials

Durable, low cost, energy efficient materials



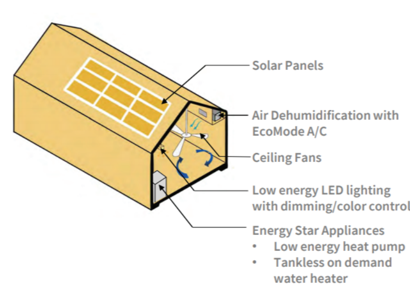
We implemented LED lighting for all the fixtures inside the house to help reduce energy usage. LED lighting fixtures have a longer life span along with a reduction in heat gains, which lowers cooling loads and prevents overheating. LED bulbs come in a wide range of shapes and sizes, lighting color, and dimming capability, allowing each room to have a custom lighting design for better long lasting comfort. When feasible, fixtures will be installed with dimmable controls to allow for brightness and distribution control. When feasible, fixtures will be installed with dimmable controls to allow for brightness and distribution control.

Household Lighting Fixtures to include as below:

-12 Watt LED Surface Wall Sconce
-1.5 Watts per ft LED Tape
-16.5 Watt LED Vanity Light
-12 & 16 Watt LED surface ceiling light
-12 & 24 Watt LED pendant
-76 Watt LED Ceiling Fan

Technology

High efficiency systems
- 20% more efficient cooling*
- 200% more efficient heating*



* Compared to traditional residential HVAC systems

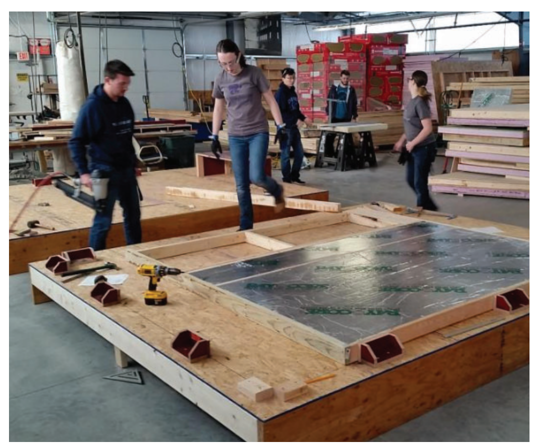
ENGINEERING

Technical Approach

During the fall 2019 semester, the studio and its leaders first worked diligently to research the neighborhood and its specific challenges related to housing. Research work enabled the studio to convince the owners of the project's merit, redefining the scale and approach to affordable housing. This argument compelled the partners to invest in the project vision of a smaller, higher quality, net-zero home.

While the Net Positive Studio carried out its research work we quickly shared what we were learning about the neighborhood's existing housing stock: specifically, that many of the original homes in the neighborhood were small homes, built with small budgets by their working-class owners. Approaching the problem with a more compact home that maximizes amenities presented several new opportunities: construction costs could be much lower; the home would fit better in with the surrounding neighborhood home sizes.

Before construction began, the team studied their prefab approach with a full scale mockup of a wall corner and roof. Each panel went through a comprehensive design to coordinate structural components, sheathing, and insulation in the BIM model; a fabrication sheet was then produced for each panel, choreographing the assembly of framing, SIP pieces, special nailing for wall bracing, and the other subsequent layers. The Raycore SIP blanks were then cut to size along with other framing members, and assembled on a panel framing platform, using carefully placed jig blocks to ensure panel squareness and dimensional accuracy. After sheathing and exterior insulation is installed, a weather-resistant OSB outer nailbase completes the exterior of the panel, and lastly windows are installed and sealed inside and out.



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While site work is being carried out, the studio will construct envelope panels with partial finishes, along with kitchen and bath components, off-site in an indoor facility owned by APDesign in Manhattan, Kansas. Students will complete all of these above-slab components and test-fit them to exhibit the house by the end of the Spring 2020 semester, demounting the components and preparing them for transport in May. By the summer 2020, Eco Devo received the components and Prof. Gibson administered the final assembly of the prefab components and installation of systems by subcontractors hired by Eco Devo. At the beginning of the Spring 2020 semester students continued their program integrated into two courses, Architectural Design Studio 8 (ARCH807) and Architectural Design Communication (ARCH808). The class also built a wall and roof panel mock-up construction, with direct guidance by Prof. Michael Gibson, project advisor and also a licensed architect to better understand their design before construction.

TEAM APPROACH

Prefab Process


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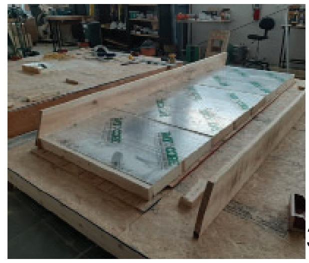
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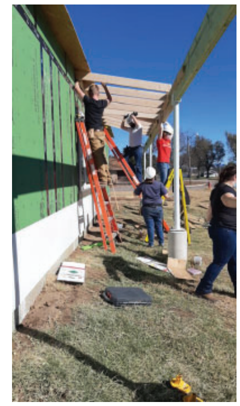
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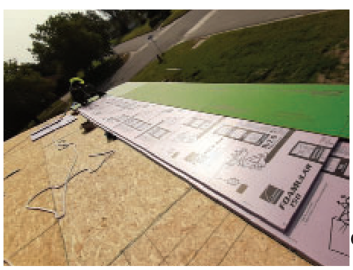
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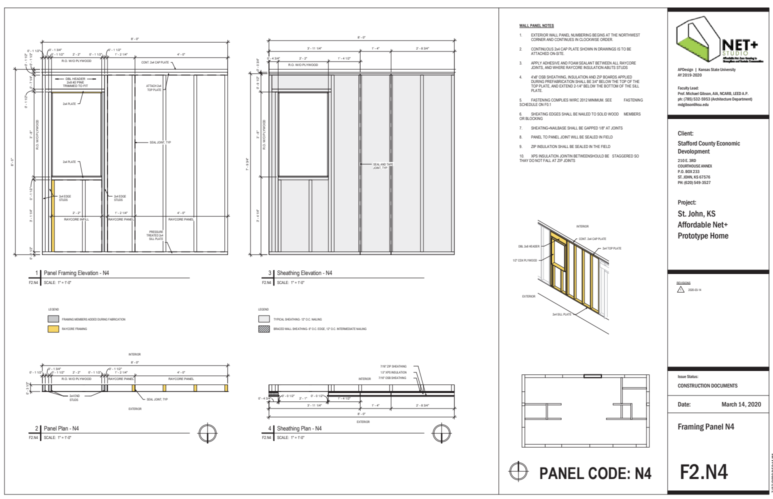
Each panel went through a comprehensive design to coordinate structural components, sheathing, and insulation in the BIM model; a fabrication sheet was then produced for each panel, choreographing the assembly of framing, SIP pieces, special nailing for wall bracing, and the other subsequent layers The Raycore SIP blanks were then cut to size along with other framing member, and assembled on a panel framing platform to produce wall panels [1], using carefully placed jig blocks to ensure panel squareness and dimensional accuracy. After structural sheathing and exterior insulation was installed, a weather-resistant OSB outer nailbase completes the exterior of the panel [2]. Roof panels were made in just two sizes, and consisted of rafters with Raycore SIPs as the secondary structure, nailed together with temporary jigs [3]. The panels were stacked neatly and then loaded onto a semi for the 170-mile trip to St. John [4 and 5]. On site, wall panels were erected one at a time on the completed foundation [6], and then interior posts, the ridge beam, and continuous top plates were added to prepare the structure for the roof [7]. The roof panels were places one at a time using a telehandler boom [8] and once they were set, the roof was sealed and above-deck continuous roof insulation was installed under a weather-resistant OSB nailbase [9]. Next, windows and doors were installed along with final seam-sealing of the walls [10]. The prefabricated porch roof and columns were then installed [11]. With a dried-in envelop, prefabricated interior walls were set and ceilings were framed in the field [12].

INNOVATION

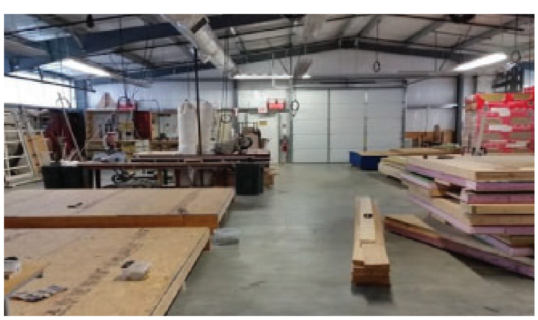
Pre-Fabricated Wall Panels

One of the main aims of the Net Positive Studio is to demonstrate an innovative way to create high performance homes that are affordable and easily adaptable to the masses. From the beginning of the project, the studio intended to use prefabrication to keep costs low and meet the budgetary needs of the client. This approach allowed us to control the assemblies of the construction more than traditional on-site stick frame construction would allow. In turn, this strategy allowed us to achieve the efficient construction assemblies needed to create a net positive house.

The construction system proposed is a prefabricated panel construction with a reinforced, insulated concrete slab on grade. The prefabricated panels consist of RAYCORE Structural Insulated Panels (SIPs). The RAYCORE SIPs being used in this design consist of 2x4 studs, 16" O.C. with polyurethane foam insulation between them. This polyurethane foam provides a high R-value and is extremely light, creating an assembly that's well-insulated, extremely light weight, rigid, dimensionally accurate, and with a very low vapor permeance. The assembly is then wrapped on both sides with a foil radiant vapor and air barrier, allowing the envelope to keep heat out during the summer and heat in during the winter. The house is designed around the four-foot module of the SIPs, providing a dimensional system for laying out the house and placing window openings, while minimizing waste and saving labor during the team's prefab work.



Further, the team developed an innovative approach to prefabricating the roof panels that produces a highly efficient but simple roof-ceiling assembly, eliminating wasted and drafty attic space from the house while quickly providing a walkable roof substrate on site during assembly. Furring strips provide air layers between panels and interior finishes to work with the assemblies' radiant barrier, while allowing space for electrical cabling and receptacles that will not compromise the thermal and air barrier of the house. Overall, these assemblies will also give the user flexibility to make changes and upgrades to finishes and systems later on.



INNOVATION

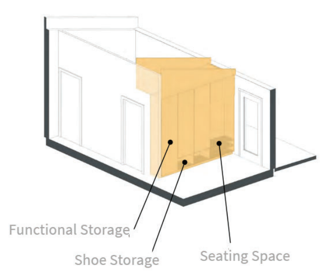
Casework

In order to provide the team with the clarity for the assemblies and details, a BIM model was developed detailing the prefabricated panel structure. Assembly details were mocked up at full scale to explore connection details between the wall and roof panels and the openings.

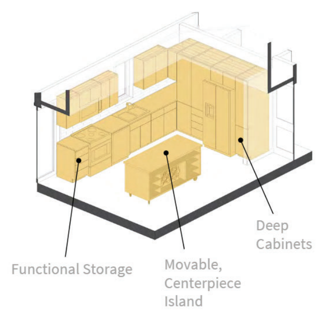
The studio was faced with the problem of providing adequate storage for the family in a small house. In order to solve this problem the studio opted to design and build custom casework for the house, constructing bookshelves, closets, and built-ins. Designed in Rhino, the case work was made to be minimalist, the case work is used not only to provide storage, but to provide a clean, uniform and functional aesthetic. Casework at the entry helps to make the space double as a mud room, providing storage for coats and shoes that were incorporated into a builtin bench.

The entertainment center is designed to be flexible and easily reconfigured to accommodate for changing technology. A new challenge arose when working on the kitchen casework, how to make it functional and small, while still providing for the needs of the homeowner. The solution came in placing the sink and other appliances in the optimal placement before adjusting the cabinetry around it. The depth of counters and cabinets around the windows and sliding glass door are reduced to allow for optimal illumination, while additional depth was added around the refrigerator to provide additional storage without taking away overall kitchen space.

With a lack of total workable counter space, there was a need to provide more storage and workspace elsewhere in the kitchen. While a kitchen island would solve this issue, it would create a new issue by reducing the adaptability of such a small kitchen. The solution was to transform the island into a flexible piece of furnishing, leaving it unattached and adding wheels to the island. This allows for the island to be positioned by the homeowner to fit the situation at hand, giving them the most out of their kitchen.



Entry Casework



Kitchen Casework

Wall storage pieces were designed for both the entertainment space and bedrooms, eliminating the need for homeowners to buy bulky and ill fitting furniture. Having specifically designed casework in each room allows the space to be effectively utilized while providing ample storage options. To keep consistency in the casework, all of the individual pieces were placed in a BIM model before being cut using a CNC router. The fabrication of these elements used standard construction practices, but unique to the project is the selection of ½" furniture grade plywood when able and the elimination of traditional facia boards.

INNOVATION

Mechanical Systems

Air handling units, or AHUs, heat, cool, and filter conditioned air and distribute air throughout the house through ducts. The AHU also has a return duct which delivers used air back to AHU where it is filtered and conditioned. For our Net Positive house, we selected a Mitsubishi - M-Series Air Handler for its cost and efficiency. Secondary benefits of this AHU system are its small size, its washable and reusable filter, and its ability to operate in a dehumidification-only mode ('eco mode') which will increase the ability of the home to use natural ventilation and keep occupants comfortable at more economical temperatures.

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High-Efficency Plumbing Fixtures

A tank-less water heating system will generally help the user to save money over the system's lifetime, and keeping energy costs low. A considerable advantage of tank-less units is their longer lifespan and ability to be serviced. A standard, high-quality water heater will last roughly a decade, whereas tank-less models' function for twice as long. Tank-less water heaters are also much smaller than bulky tank heaters, requiring less mechanical space: an important benefit for the prototype home. We will be using two tank-less water heaters, an EcoSmart ECO 11 for the independent bath and an EcoSmart ECO 18 for the master bath, kitchen and washer. Because the tank-less water heaters do not rely on a reserve of hot water to meet demand, the entire house has an equal supply of hot water 24/7.

Concrete Slab

The continuously insulated concrete slab floor will calm the extremes in daytime temperatures. It achieves this by absorbing heat during the day and releasing it in the evening when the excess can be either released through natural ventilation, or it can be used to heat the space as the outside temperature drops.

Porch Roof Structure

The porch structure is composed of a ladder frame which is connected back to the house, rather than constructed of cantilevered rafters. Using a ladder frame simplified prefabrication of the house while also ensuring that insulation could continue unbroken at the transition between wall and roof, preventing potential thermal bridging and air leakage. The south side of the porch is supported by a built-up beam that rests on steel pipe columns that will be prepared off-site with base plates and brackets to speed construction.

Thermal Resistance Values of Envelope

	Installed Insulation R-Value [h*ft2*°F/Btu]	Assembly R-Value [h*ft2*°F/Btu] [1]
Foundation Slab	R-10	-
Walls	R-26 + R-7.5 continuous	R-29.5 [2]
Windows	-	R-4.0 (U-0.25) [3]
Roof/Ceiling	R-26 + R-15 continuous	R-36.9 [2]

[1] Total assembly R-Value with air films

[2] Determined using area-weighted summation from ASHRAE Parallel Path method for cavity assemblies; this value accounts for all layers of the wall assembly, including thermal bridging through framing members. The radiant barrier in walls and roof has not been assigned an R-value in these assembly R-values, but would contribute to the thermal performance of the walls and roof.

[3] Manufacturer rating using NFRC-certified testing methods

HVAC Loads and Equipment Selection

	Loads	Capacity	Efficiency Rating
Heating	14,354 BTUH [1]	18,000 Btu/h at 9°F	13.6 HSPF
Cooling	20266 BTUH [1]	27,000 Btu/h at 95°F [2]	18 SEER

[1] From CoolCalc software, using simplified ACCA Manual J process.

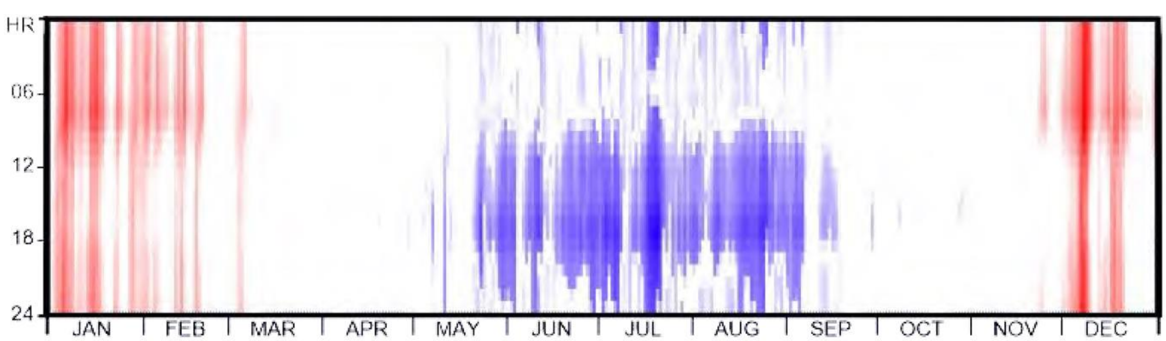
[2] The cooling capacity is more than needed but choosing the equipment to satisfy the heating load is the priority.

Whole Building Annual Energy Analysis Results

	Energy [1] [kWh]		HVAC Loads [2] [KWh]		HVAC Fuel [3] [kWh]		Total Energy	PV Energy Production
	lighting	equip	heat	cool	heat E	cool E		
Jan	80.47	338.28	391.69	0.00	178.04	0.00	**596.79**	359.94
Feb	72.68	305.53	156.40	0.00	71.09	0.00	**449.30**	372.29
Mar	80.47	338.28	26.28	0.00	11.94	0.00	**430.69**	497.53
April	77.87	327.36	0.26	0.62	0.12	0.15	**405.50**	534.04
May	80.47	338.28	0.10	121.15	0.05	30.21	**449.01**	589.14
June	77.87	327.36	0.00	306.33	0.00	76.39	**481.63**	593.47
July	80.47	338.28	0.00	411.81	0.00	102.69	**521.44**	593.30
Aug	80.47	338.28	0.00	369.31	0.00	92.10	**510.84**	588.19
Sept	77.87	327.36	0.02	107.86	0.01	26.90	**432.14**	488.02
Oct	80.47	338.28	0.10	1.27	0.05	0.32	**419.11**	432.24
Nov	77.87	327.36	15.64	0.00	7.11	0.00	**412.34**	343.91
Dec	80.47	338.28	375.56	0.00	170.71	0.00	**589.45**	316.18
Annual	947.46	3982.92	966.04	1318.35	439.11	328.77	**5698.25**	**5708.26**

[1] Lighting loads assumed an all-LED house with optimum use of daylight. All occupied rooms achieve an average daylight factor greater than 2%. Equipment loads include electric point-of-use, tank-less water heating and are based on utilization estimated from Energy Star for the appliances specified for the house. Appliances for which no Energy Star information was provided were assigned utilization values based on typical usage.
[2] Loads included occupancy of 4 people and constant ventilation rate of 0.2 ACH, accounting for the ventilation rate of systems and their efficiency ratings.
[3] Fuel utilization for space heating and cooling used the following efficiency factors: SEER 18 for cooling, and HSPF 13.6 for heating. The manufacturer's HSPF was derated to 7.6 (COP=2.2) according to climate factors, using HeatCalc.xls.

Hourly Heating and Cooling Visualization



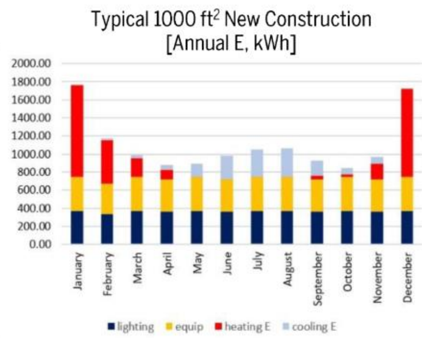
Heating Cooling Heating

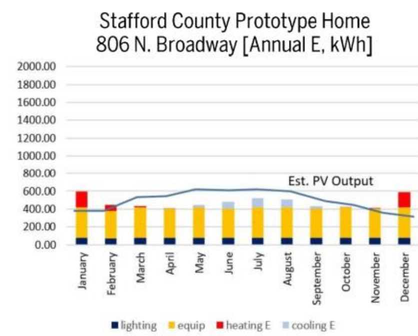
Whole Building Annual Energy Analysis Results
Comparison w/ Base Building

Energy Analysis Summary

EUI: 17.9 kBtu/SF per year

Annual Energy: 5,625 kWh
78% less than typical new construction
Annual Energy Costs: $0
Passive Performance: 56% of the year
no heating or cooling required to maintain comfort due to passive design features

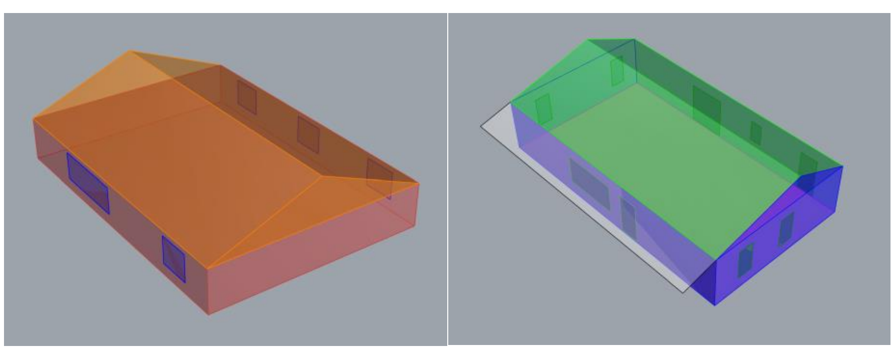




	Annual Lighting Energy [kWh]	Annual Equipment Energy [kWh]	Annual Heating Energy [kWh]	Annual Cooling Energy [kWh]	Total Annual Energy [kWh]	Floor Area [SF]	**EUI [kBtu/SF]**
Typ New Construction [1]	4378	4378	3036	1483	13277	1000	**45.3**
806 N. Broadway Design	947	3983	439	329	5698	1087	**17.9**

	Lighting Energy - $	Equipment Energy - $	Heating Energy - $	Cooling Energy - $	**Total Energy - $**	Eproduced [kWh]	PEfrac	**HERS Index [PRELIM]**
Typ New Construction [1]	$525	$525	$205	$178	**$1,434**		1.00	100
806 N. Broadway Design	$114	$478	$13	$39	**$644**	5708	0.00	0

[1] Typ New Construction Home assumed IRC 2012 prescriptive envelopment minimums and current EPA efficiency minimums for equipment.



Above: Base building model and design model used for energy analysis.

Energy Analysis Model and Zone Settings

	"New" House			Design		
Envelope	R	U	Notes	R	U	Notes
Exterior Walls	20.000		*IRC 2012 Minimum*	29.500		*2x4 Raycore + R7.5 c.i.*
Operable Windows					0.250	*Dbl pane, Low-E, Argon - From Interstate*
Fixed Windows					0.250	*Dbl pane, Low-E, Argon - From Interstate*
Roofs	49.000		*IRC 2012 min (ceiling)*	36.900		*2x4 Raycore + R15 c.i.*
Interior Floors						
Slabs	-		*uninsulated*	10.230		*4" conc. + R10 c.i.*
Below Grade Walls						
Loads		**unit**				
Natl Air Infiltration Rate	1	ACHnat	*based on HERS std SLA*	0.16	ACHnat	*1 ACH50...typ SOTA bldg [ASHRAE 2005]* *~ ACHnat = ACH50/20*
Total Lighting Power	500	W		108.7	W	*Ave hourly total lighting load for 24h day*
Lighting Power Density - IP	0.5	W/SF	*MEEB*	0.1	W/SF	*80% lighting energy reduction w/ daylight*
Lighting Power Density - SI	5.38	W/m^2		1.08	W/m^2	
Lighting Schedule	AllOn			AllOn		
Equipment Power Density - IP	0.5	W/SF	*MEEB*	0.25	W/SF	
Equipment Power Density - SI	5.38	W/m^2		4.54	W/m^2	*Using actual appliances*
Equipment Schedule	AllOn			AllOn		
Equipment Efficiency		**unit**				
Heating Setpoint	70	F	*HERS ref bldg std*	68.5	F	*per ASHRAE 55 - PMV model*
	21.1	C		20.3	C	
Cooling Setpoint	75	F	*HERS ref bldg std*	80.1	F	*per ASHRAE 55 - PMV model*
	23.9	C		26.7	C	
Heating	78	% AFUE	*HERS ref bldg std - gas*	7.5	HSPF	*13.6 HSPF derated to 7.5 due to climate*
Heating Efficiency	0.78	COP	*COP = AFUE/100*	2.20	COP	*Seasonal Average*
Cooling	13	SEER	*HERS ref bldg std*	18	SEER	
Cooling Efficiency	3.43	COP	*COP = SEER/3.792*	4.01	COP	*Note: did not use EER, but conversion factoring latent heat*

Floor Area	1000	SF		1087	SF	*Floor 1*
Total Area	1000	SF		1087	SF	*Total*
	92.94	m^2		101.02	m^2	
Total Interior Volume				11929.00	ft^3	enter this manually
				337.8	m^3	enter this manually
Daylight Autonomy Target		lx				
Occupancy Schedule	9	hrs/day	M-F	0-0-0-0-0-0-1-1-1-0.2-0.2-0.2-0.2-0.2-0.2-1-1-1-1-1-1-1-0-0		
	16	hrs/day	Sa-Su	0-0-0-0-0-0-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-0-0		
Occupants	4	persons	(1/bedroom + 1)	4		
Occupant Density	0.043	p/m^2 per occupant		0.040	p/m^2 per occupant	

Infiltration Calculation

Code V - people		CFM		30	CFM	7.5 CFM fresh air per person (ASHRAE 62,2 - 2013)
Additional code V per flr area		CFM		32.61	CFM	3 CFM per 100 ft^2
Total V		CFM		70	CFM	
CFMv to ACHv calculation		ACH		0.35	ACH	mechanical V converted to ACH
HRV efficiency factor				69.00%		
Effective ACHv (after HRV)		ACH		0.11	ACH	ACH * HRV efficiency %
ACHnat		ACH		0.05	ACH	*1 ACH50...typ SOTA bldg [ASHRAE 2005]* *~ ACHnat = ACH50/20*
Total ACH	1	ACH		0.16	ACH	ACHv + ACHnat
		ACH		0.2	ACH	Used in model -- rounded up

Weather data used: USA_KS_Hutchinson.Muni.AP.724506_TMY3.epw

Equipment Energy Utilization Spreadsheet

	UTILIZATION	kW*h ANNUAL E CONSUMED	% of total	NOTES
BEKO Dishwasher - model DDN25401X	epa	234.0	6.6%	
BEKO 24" Front Load Washer - model WMY10148C2	epa/mfr	86.0	2.4%	does not include water heating
BEKO 24" Ventless Heat Pump Dryer - model HPD24412W	Canada energy guide/mfr	208.0	5.9%	
BEKO 30" Refrigerator/Freezer - model BFBF3018SSL	epa	444.0	12.5%	
LG 47LS5700 47'' 1080p LED-LCD TV	epa	109.0	3.1%	
Panasonic ERV - model FV-10VE	constant	560.6	15.8%	64 watts at 0.1" w.g. static pressure *8760h
BEKO 30" Pro-Style Induction Range - model PRIR34450SS	0.5h/day burner	401.5	11.3%	2200W 6" burners on high
	0.25h/day stove	219.0	6.2%	2400W estimated, 9.8kW max appliance rating
BEKO 1.5 cu-ft Microwave, with Convection Oven, 300CFM, Stainless				
ECO 11 and ECO 18 Tankless Water Heaters	est	1080.0	30.5%	90 kWh per mo from 3 bed, 4 occupant comparison home w/ similar equipment
Misc additional small appliances and electronics	est	200.0	5.6%	Laptop, small appliances, misc plug loads
Typical Total Annual Equip Energy (kWh)		**3542.1**		kWh
Ave Equip Power (W)		404.3538813		W
floor area		89		m2
Estimated Ave Equip Power Density		**4.543302037**		**W/m2**